

## Final Report

# Improving the recyclability of mixed plastics: Removable colour systems



This R&D project assessed technologies and techniques that enable colour to be removed from rigid plastic packaging during recycling. This increases the quality and value of the recycled material and widens the range of end markets available to it. It was conducted in collaboration with packaging manufacturers, suppliers and the retail supply chain.

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Creating Sustainable Solutions for Polymers and Recycling

**Front cover photography:** [Coloured rigid plastic packaging].

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# Executive summary

In the retail environment colour is used to cut across language barriers and as an aid to fixture navigation not only for consumers' benefit but also to help overcome the hurdle of getting products onto the shelf. Brand owners use colour to give their product shelf standout and consumers link the colour with the product and the brand.

This project investigated removable coloured coatings, the use of shrink sleeves to replace in-mould labels and the use of 'self peeling' label technology to replace conventional pressure sensitive labels. These systems could enable colour to be removed from rigid plastic packaging during the recycling process.

The objective of the project was to assess whether these innovations and techniques would enable more of the material recycled to become colourless. This would maximise the range of end markets for this material and keep it high in the value chain, maximising the likelihood of it being used in place of virgin plastic in new items.

The studies of the technical performance of each system were complemented with assessments of the economic and environmental impact of introducing the technologies.

Trials were conducted on a range of different packaging samples to ascertain how sensitive typical Near Infrared (NIR) automatic plastics sorting systems are to different decoration methods when identifying the polymer type of the pack. The samples incorporated a range of polymer types including clear and coloured base materials that were decorated with a range of labelling techniques. The results of these trials demonstrated that direct printing with ink did not interfere with spectroscopic identification while the opaqueness and thickness of labels could play a significant role in the ability of the sorting equipment to identify the polymer type of the pack. The polymer types of the pack underneath labels with clear areas were readily recognised while heavily printed thicker gauge labels resulted in greater difficulties with polymer identification.

## Use of Coloured Coatings

Coating trials with removable ink were successful. PET sheet material was printed with differing levels of ink coverage and then thermoformed. The ink used was approved for indirect contact with food, that is, the ink was applied to the outside of the tray. During thermoforming the ink demonstrated good adhesion and resistance to scuffing.

Washing trials were carried out under varying conditions. The ink was easily removed when the flakes were subjected to shearing forces however when the flakes exhibited a curl, the softened ink was protected to an extent and then less readily removed. Consequently completely clean flakes were not produced from these samples. However, since a significant amount of the ink was removed it would be possible, with some further development work, to optimise the ink system to give good scuff resistance and be fully removable in conventional recycling washing processes.

The washed PET flake samples were also treated to a laboratory scale (URRC UnPET®)<sup>1</sup> recycling process used to render PET recyclate safe for use as food contact material. The resultant flake was then evaluated by gas chromatography / mass spectroscopy (GC-MS) and compared to a batch of standard food grade recycled PET. The results showed that there was no difference in the volatile behaviour of the two materials indicating that both samples would comply with the food grade regulations. As with all new food contact packaging overall migration testing would need to be completed before the packaging could be used.

NIR identification tests of the ink-coated trays demonstrated that the underlying polymer type could be identified by automatic sorting systems based on NIR. Samples coloured with a single pass ink (one layer) gave a strong signal and resulted in 100% PET polymer recognition.

The commercial acceptability of the removable colour coating technology was evaluated by sending samples of the trays together with photographs of mock-up samples filled with mushrooms to the Packaging Managers at seven major UK retailers. The feedback received indicated that retailers are enthusiastic about this development and generally liked the look and finish of the coloured trays. However they would need to see results of further

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<sup>1</sup> The United Resource Recovery Corporation (URRC) hybrid UnPET® Process, chemically etches PET flake and is recognised worldwide as a fully approved food grade recycling process.

testing of a range of elements such as colour depth, scratch and scuff resistance, ink migration tests and optimisation of depth of colour.

In summary the trials conducted suggest that the potential for direct ink printing technology is very promising. However it is not yet fully optimised at this stage and could be enhanced by further formulation adjustments that explore the importance of the nature of the surface, the degree of coating cross-linking, the degree of pigment hydrolysis and the amount of shear applied in additional processes such as dry cleaning and friction washers.

### **Use of Shrink Sleeves**

The investigation of the use of shrink sleeves to replace in-mould labels showed that the technology was readily available and constrained mainly by the slightly higher cost of shrink sleeves and the capital costs implied in changing from in-mould labels. However, if the container shape (parallel sides or slight taper) allowed the use of stretch sleeves, the overall economic impact would be positive due to the lower cost of the stretch sleeves and application equipment.

### **Use of Self-Peeling Labels**

The 'self peeling' labels investigated are based on the principle of differential expansion under thermal conditions. The labels fully adhere to the packaging item under ambient temperatures, however at higher temperatures >50°C the expansion of one layer within a two layer film causes differential expansion, thus resulting in peeling of the film away from the packaging item under caustic conditions. This label technology was demonstrated to provide excellent separation of labels and polymer during simulated recycling washing trials.

### **Environmental Assessment**

The differences in environmental impact between the current pack types and the removable colour systems investigated were all found to be marginal overall.

Changing from pigmented HDPE to clear HDPE through the use of a removable stretch sleeve was shown to result in a slight improvement in all environmental indicators, except water use. The reduction in global warming potential was around 7%.

Wash-off labels show insignificant change in environmental performance, which is to be expected, as there is minimal difference between a wash-off label and a normal full-body label.

Changing from in-mould labelled PP pots to clear PP pots with a shrink sleeve was shown to have a net improvement against abiotic depletion and energy demand indicators, but an increase in global warming potential and water use. The modelled differences were small, and may not be statistically significant.

Changing from pigmented PP to clear PP direct printed with removable ink has a slightly detrimental environmental impact (global warming potential around 5.5% higher and water use 1.6% higher). However, as with all trials, the results may not be representative of commercial scale operations and this technology is still in development. We would recommend that during further development, opportunities are found to reduce the environmental impact of this technology.

It should be noted that in the environmental assessment it has been assumed that removable colour systems will not change recycling rates or yields of material recovered per se. However if the higher economic value of producing clear plastic from coloured packaging were to drive increased collection and reprocessing or result in increased direct substitution for virgin plastic, then the net impact would be highly positive.

### **Conclusions**

Overall the project found that there are viable technologies to enable colour to be removed from rigid plastic packaging during the recycling process that will have relatively little additional impact on the environment. If these technologies were promoted to the packaging supply chain then the mixed plastics recycling stream would ultimately have a higher value and the recovery of mixed plastics would be more attractive to recycling businesses. If this increased recycling levels then the improved environmental impact of a higher rate of mixed plastics recycling would very quickly outweigh any of the slightly negative impacts associated with the adoption of some of the technologies.

The status of the various technologies can be summarised as:

- Removable ink is a process that showed promise as a novel means of adding colour but needs further development to make it commercially viable. The trials here have been conducted with PET since it required no significant treatment prior to application. The use of other plastics such as PP, HDPE, PVC and PS would also need to be validated to understand the general validity of this approach. In general these polymers would be expected to release the inks more readily than PET.
- Use of shrink sleeves as an alternative to in-mould labels gives immediate benefits for recycling but adds capital cost for the application equipment.
- Use of stretch sleeves or self-peeling labels as an alternative to masterbatch for certain types of container gives immediate recycling benefits.
- Currently while there are minor technical issues associated with the full roll out of the removable ink technology that can be resolved by further detailed research, there are financial considerations limiting but not preventing the adoption of the sleeve and label technologies. The adoption of these technologies to a wider range of packaging could be encouraged with flagship products and campaigns by industry or packaging organisations, brand owners, retailers and packaging business promoting these recycling friendly forms of colouration and decoration.

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# Glossary

ABS	Acrylonitrile Butadiene Styrene
ADP	Abiotic Depletion Potential
APET	Amorphous Polyethylene Terephthalate
BOPP	Biaxially Orientated Polypropylene
CFC'S	Chlorofluorocarbons
CML 2001	2001 characterisation factors from the Institute of Environmental Services (CML), University of Leiden, The Netherlands
CO <sub>2</sub>	Carbon Dioxide
CSD	Carbonated Soft Drinks
EPS	Expanded Polystyrene
EVA	Ethylene Vinyl Acetate
GWP	Global Warming Potential
HDPE	High-Density Polyethylene
HFC'S	Hydrofluorocarbon
IML	In-Mould Label
IPCC	Intergovernmental Panel on Climate Change
Kg sb-eq / tonne	Equivalency to 1 Kg antimony per tonne (unit of ADP)
LLDPE	Linear Low Density Polyethylene
MRF	Materials Recovery Facility
NIR	Near Infrared
PC	Polycarbonate
PERN	Packaging Export Recovery Note
PET	Polyethylene Terephthalate
PETG	Polyethylene Terephthalate Glycol
PP	Polypropylene
PRF	Plastics Recovery Facility
PRN	Packaging Recovery Note
PS	Polystyrene
PVC	Poly Vinyl Chloride
rHDPE	Recycled High-Density Polyethylene
rPET	Recycled Polyethylene Terephthalate
rPP	Recycled Polypropylene
Sq.m	Square Metre
TPA	Tonnes per annum
TPU	Thermoplastic Polyurethane
URRC	United Resource Recovery Corporation
UnPET®	Unpet® is a registered trademark owned by United Resource Recovery Corporation.

## 1.0 Objective of the Project

Coloured plastics are manufactured by adding a concentrated colourant, known as masterbatch, into the molten plastic. This means that the colour is permanent and is embedded within the structure of the plastic. During recycling, coloured articles can be sorted by polymer type and colour and coloured items are reprocessed as 'Jazz' grade into other coloured components.

Since the highest value plastic recyclate is colourless food grade material, this project investigated technologies that could be used to add colour that is removable during recycling. This would mean that coloured plastics have the potential to be reprocessed into higher value materials, and may therefore be acceptable in a wider range of end markets. Provided the appropriate conditions have been met they could then be used to substitute for virgin material in food contact applications.

## 1.1 The Role of Colour

Recognising the importance of colour in branding and why brand owners like to use brightly coloured packaging as part of their overall brand offer is crucial to gaining commitment from the marketing functions within the major branded manufacturers. The marketers are frequently the key decision-makers on commercialisation of physical and artistic features of a pack. Over significant periods of time, brand equities will have been built and a reluctance to modify such key attributes, for technical reasons alone, is highly likely. Marketeers and Packaging Managers will need to be confident that the perception from the consumer viewpoint is maintained, and in an ideal world, enhanced.

## 1.2 Context and background

Colour has always played a primary role in branding and packaging. Colour is used to convey messages or trigger associations that encourage the consumer to buy. Purple, gold and black are typically used to indicate exclusivity, expensiveness, luxury and quality, dependent on the nature of the product. Colour is also used to convey information about who a product is aimed at or how it is made.

Colour is the first thing an observer notices about a package. It is recognised before shape, and the graphic or text content is recognised last. This makes colour one of the most important motivators of a purchase decision (Soroka 1996). Many well known brands are instantly recognisable because of the colour of the packaging.

With foods and pharmaceuticals packaging, non-toxic inks are essential and these must be highly resistant to possible leaching into the contents of the package.

Alternative systems and novel coatings for plastic packaging that could be used or that are currently being used to apply removable decoration have been reviewed here. In some cases these have been further researched to determine their ability to replace the strong masterbatches currently used to create bright colours that are used to give products shelf appeal and stand out appeal.

It is recognised that it is not always preferable to remove colour completely from the brand experience or the category. Removable colour systems would not only maintain the shelf appeal and product differentiation but also allow these articles to be recycled with the clear or natural flake stream and significantly increase sorting yields and thus material diverted from landfill.

## 2.0 A Review of Coating, Labelling and Surface Modification Techniques

A number of technologies exist for colouring plastic packaging items with coatings rather than by bulk colouration of the plastic, offering the possibility of colour removal during recycling.

A number of these technologies have been investigated. Commercial ready options include removable organic barrier coatings and full-body labels. Newer technologies such as colour removal under anaerobic conditions (reductive de-colourisation of pigments), and direct printing have been examined further to establish likely timeframes and hurdles for commercialisation. Each technology shows promise as an option for reducing or eliminating the impact of coloured plastic packaging on recycling systems.

Developments such as peelable labels, and new sleeving materials, could offer cost effective opportunities that still meet all the aesthetic requirements and enable more effective resource recovery from this highly diversified component of the waste stream.

### 2.1 Colour coating technologies

A removable colour coating for plastic packaging items would allow for use of the different colours desired by brand owners for their packaging, yet during recycling, would revert to natural or white coloured polymer with higher market value and access to a wider range of end markets. The coloured packaging could be labelled with product and marketing information as it is currently.

Organic coatings are already used for providing barrier properties for plastic packaging (Lange & Wyser 2003). The same coating technology could provide colouration through pigments or dyes, as well as barrier properties. SIPA (Smartcoat™) and PPG (Bairocade) are two existing, commercial organic barrier-coating technologies on the market.

DuPont has also developed a two-coat electrostatic spray process (Hanny 2002) based on a water-soluble barrier base coat and a water-resistant protective topcoat. This has not been commercialised, but the technology is available for licensing (Barsotti & Winter 2007). There is a patent (Craun & Rance 2001) on strippable coatings that could be applied as an aqueous latex and removed during the caustic wash step in recycling, this system has also yet to be commercialised.

#### 2.1.1 SIPA Smartcoat™

SIPA's Smartcoat™ was developed to apply a barrier coating after bottle production. These barrier coatings are intended to improve barrier properties to light, moisture, carbon dioxide or oxygen, as an alternative to blending high barrier resins into PET or using a co-extruded barrier layer in the PET bottle. The coatings consist of a barrier layer and a protective topcoat. Curing is by ultraviolet (UV) light after flashing off the solvent in an oven.

**Figure 1:** Example of PET bottles with SIPA Smartcoat™ (Source: SIPA 2009)



The limitations of this system are that it is currently only used for PET bottles, and will require modification for bottles from other plastics, and for non-bottle packaging such as jars and cups. The SIPA system is not universally applicable as irregularly shaped packages are not suitable for a dip and spin coating technology, and it may not be possible to produce opaque colours with the coatings.

### *2.1.2 PPG Bairocade*

PPG manufactures coatings and launched Bairocade as a barrier coating for PET bottles in the mid 1990s. The technology comprises an epoxy-amine barrier coating (Nugent, Niederst & Seiner 1996) applied electrostatically through spray coating, then oven cured. As with the SIPA system, a topcoat would generally be applied to protect the barrier layer. Layers are only 1-6 micron. The PPG barrier coatings have been applied to HDPE and PP as well as PET bottles.

For colouration, the PPG system has been demonstrated to be able to apply translucent colours to PET bottles. The demonstrated coatings are translucent, for example amber or green tints for PET beer bottles. Opaque colours are unlikely to be possible given the thinness of the coating applied.

The PPG Bairocade coating is generally known to not interfere with recycling (Murphy 2001). Testing has shown that the barrier layer can be washed off from PET beer bottles using a modified hot caustic washing with >99.9% removal efficiency after 15 minutes (Kegel & Kosior 2001). Testing also shows that extremely rapid removal could be achieved in an acetic acid solution however this is a change from normal recycling practice of using hot caustic solution.

The PPG Bairocade coatings would appear suitable for providing removable colour coatings to a range of plastic packaging items, so long as translucent colour coatings are acceptable. Application by electrostatic spray may increase the variety of shapes that could be effectively coated beyond the cylindrical bottles and jars able to be coated by the SIPA Smartcoat™ system.

### *2.1.3 Decolourisation during extrusion*

Gupta et al. 2008, describe a novel process for the oxidative decolourisation of green and blue coloured PET bottle flakes, using an aqueous solution of hydrogen peroxide (H<sub>2</sub>O<sub>2</sub>). Despite decreases in intrinsic viscosity (IV) values, the bleached flake still exhibited useful PET molecular weights. This works on phthalocyanine and anthraquinone organic dyes used for blue and green tints. The most effective agent described is polymethylhydrosiloxane (PMHS), which has the advantage of being inexpensive, stable and safe to handle. Organic peroxides were also described as usable. The best decolourisation was achieved with red and violet colours.

Milliken produce polymeric colourants consisting of organic pigments that are reactively processed to couple with the polymer substrate, such as PET and PP. Milliken has demonstrated that it has pigments that can be denatured by redox reactions through use of an additive that could be added to the extruder during reprocessing by the recycler. Milliken has a patent application filed for this technology (Connor & Keller 2006).

### *2.1.4 Surface Dyeing*

Bayer Material Science has developed a surface dyeing process for amorphous polymers like PET, PETG, PC, ABS, TPU, EVA and nylon. The patented system called Aura Infusion has been commercialised by Replex Plastics in Mt Vernon, Ohio, who has also developed the immersion equipment for licensees of the Bayer process.

The aqueous bath can produce colour penetration of approx 0.25mm in 60sec on formed articles so that a generic stock can be coloured to order, using substantially less colourant than masterbatch that is melt compounded into the entire article.

As these dyes are suitable only for amorphous polymers, they would not be usable with HDPE or PP. It is not certain if these dyes are removable during recycling. The surface nature of the dyeing system may decrease the amount of colour imparted to the recycle, but it is unlikely to be a solution that meets the requirements of this project.

## 2.2 Direct Printing on Thermoformed Packaging

The benefit of direct printing is that the detail could be printed onto the sheet material prior to moulding. This offers the ability to print in three dimensions and to completely change the look of thermoformed packaging. Products that have a printed insert or exterior labels can be redesigned to remove component costs, thus greater cost efficiencies can also be realised.

## 2.3 Labels

The creative use of labels can be a low cost solution to signalling product identity and has the benefit of reducing the amount of packaging that needs to be stored prior to use, because generic container colour variants (i.e. clear) can be used for a range of packs to be coloured differently using labels of a different colour.

### 2.3.1 In-mould Labelling

There is a growing trend in the food industry to use in-mould labelling to decorate pots and tubs. The concept is to coat the reverse side of the label with a heat seal layer and the fusing of the film label during the moulding operation causes the label to bond permanently to the container.

The ink on the label is effectively trapped, which makes recycling these containers difficult. When the label is made of a different substrate there can be difficulties identifying the container using optical sorting systems and it may be lost from the recycling stream at the primary sorting stage. Even if the container itself is made from natural or colourless material the use of the in-mould label will downgrade it to the coloured or 'jazz' stream. Because they are permanently bonded together even after shredding and washing, the label will still adhere to the flakes. Therefore the development of a removable in-mould label would divert material from the coloured or 'jazz' stream back to high value natural recycle.

### 2.3.2 Wrap-around film labelling

Wrap-around film labels were developed to allow the labelling of PET bottles and beverage cans with reel-fed, tear proof plastic film labels. The labels can be reverse-side printed to provide a non-scuff, scratch resistant print quality. These are plain, coated Biaxially Orientated Polypropylene (BOPP) films. Plain uncoated films come in thicknesses from 19 to 50 microns, while coated films range from 30 – 70 microns. Super-white BOPP films are made with a cavitated core and specially developed outer layers, which provide a bright-white appearance. In operation, glue is applied onto the leading edge of the film via mechanically driven rollers. The film is cut to length and wrapped around the bottle or can and then glued on the trailing overlap-edge to form a complete wrap. This can have the additional benefit of packaging identification postponement. That is, containers are not decorated, branded and identified until filling. This can allow inventory reductions and hence economies of scale.

### 2.3.3 Preformed outer sleeves

Preformed outer sleeves are a relatively new format that has found application in the premium yoghurt market. A high quality print decorated outer, typically made from thicker paperboard provides both the labelling, most of the structural support and also some level of insulation for hot or cold articles. The inside liner is a very lightweight polymer tub, usually PP providing the surface for heat-sealing a peelable foil lid. Spots of adhesive attach the outer paperboard layer but the two components are readily separated to natural uncoloured PP tub with a fully pulvable and recyclable fibre sleeve.

### 2.3.4 Stretch-sleeve labelling

A more recent development of sleeve technology, which instead of shrinking the film tube to fit over the bottle or pot it uses a stretchable film, which is cut to size and then opened up and stretched to slide over the bottle or jar. It then collapses elastically to fit the shape of the container. Stretch sleeves are primarily made from LLDPE resin. Like the other unsupported film labelling solutions they are primarily printed with gravure or flexographic technology. Films can be reverse side printed to minimise ink scuffing or rubbing.

### *2.3.5 Shrink sleeve labels*

Initially made from pre-stretched polyvinyl chloride (PVC) shrink sleeves are now available on the market in Orientated Polypropylene (OPP) and Polyethylene Terephthalate (PET). Thickness ranges from 35 – 90 microns. Shrink sleeves are used to provide tamper-evidence features and can incorporate perforations. In comparison to stretch sleeving, thicker films tend to be used. As with stretch sleeving it is usual to print an opaque white base in order to give strength to the other colours used and reverse side printing minimises scuffing and rubbing.

### *2.3.6 Pressure sensitive labels*

More commonly referred to, outside the labelling industry, as self-adhesive labels, the pressure-sensitive format offer the package-labelling market a wider range of face materials and adhesives than any other method of labelling, as well as the greatest range of in-line printing and converting options. With an adhesive, which is already active and ready for immediate application, it is not surprising that they have gained popularity for a diverse range of primary and secondary labelling requirements. Labels are manufactured using paper and board, films, synthetic papers, foils and laminates, as well as having a whole range of surface treatments and top coating to meet specific applications.

### *2.3.7 Self Peeling Adhesive Technology*

The 'self peeling' labels developed by Avery Dennison are based on the principle of differential expansion under thermal conditions. The labels fully adhere to the packaging item under ambient temperatures, however at higher temperatures >50°C the expansion of one layer within a two layer film causes differential expansion, thus resulting in peeling of the film away from the packaging item.

### 3.0 Near Infrared (NIR) Sorting of Commercial Mixed Plastics Samples

The basic principle behind NIR technology is measuring the reflectivity of an object within a wavelength range of 1.1 to 2.1 nm. In this wavelength range, materials such as plastics, paper, and textiles have their own specific characteristics.

Modern sorting systems can distinguish plastics such as HDPE, PP, PS, PET, EPS, PC or PVC with ease, as well as clearly identifying cellulose-based materials such as paper, card, cardboard or wood and natural fibres. Materials that cannot be identified due to a lack of individual characteristics in this wavelength range include black plastics, which do not reflect and are therefore not measurable.

#### 3.1 Sorting Trials

A selection of packaging samples was tested in a NIR sorting process to ascertain how sensitive typical NIR systems are to different decoration methods and coverings.

The samples were selected to cover a range of polymer types including clear and coloured PS, PP and PET. They were decorated with a range of labelling techniques including self-adhesive or pressure sensitive paper and PP labels, in-mould labels and shrink sleeves.

**Figure 2:** Samples tested using NIR

Packaging Format	No. of Samples Tested
Clear, natural, coloured & surface printed pots/tubs	9 samples tested
Clear and coloured pots/tubs with self adhesive full face plastic/paper labels	8 samples tested
Clear & white pots/tubs and bottle with shrink sleeves	4 samples tested
Tubs and pots with in-mould labels	5 samples tested
Tray packaging	7 samples
Multi-layer and laminated tubs & sheet	6 samples

**Figure 3:** Samples tested showing the types of tubs, pots and trays from commercial UK retail sources that were analysed by a NIR sorting system.



#### 3.2 Trial Results

The findings suggested that direct printed packs are easily identifiable by polymer and the colour sort depends upon the level of the most common colour. Sorting of packaging with self-adhesive labels showed that the opaqueness and thickness of labels plays a role in the ability of the sensors to identify the polymer type of the pack. Labels with clear areas allowed for easy identification, and heavily printed thicker gauge labels resulted in difficulties with identification. There is therefore an opportunity to optimise label thickness to allow for the identification of the pack.

Packs with thin PVC shrink sleeves were identified by polymer type, however the heavily printed and coloured format of the sleeve meant that clear natural tubs were ejected into a coloured stream and thereby this product was lost from the higher value stream of clear/natural or light coloured (white) packaging. Also the polymer identification was limited.

Packaging with in-mould labels were readily identified by polymer type, however the heavy colouration and surface coverage meant that all products entered the coloured stream even if the tubs themselves were natural.

Overall, the trial found that the majority of packs can be readily identified using NIR, however the decoration method plays a significant role in determining the effectiveness of the detection and sorting.

## 4.0 Use of Removable Ink as a Surface Coating

The use of inks to apply surface decoration and colour is widely used. Here a removable ink was used to apply a solid colouration to sheet material that would then be thermoformed into food trays.

A variety of inks were tested to identify the best type for this application. All the inks tested were water based - containing organic pigment in an acrylic resin medium. The inks are specifically designed to print on plastic but also tailored for variable degree of cross-linking. Cross-linking increases the various resistance properties of the ink including chemical and re-solubility resistance.

As a working definition here - an ink is basically a functional coating but with the additional capability to be applied by a printing process to create an image. Typically, therefore, a variety of colours are also a key feature as well as the printing capability and the physical and chemical properties of the ink.

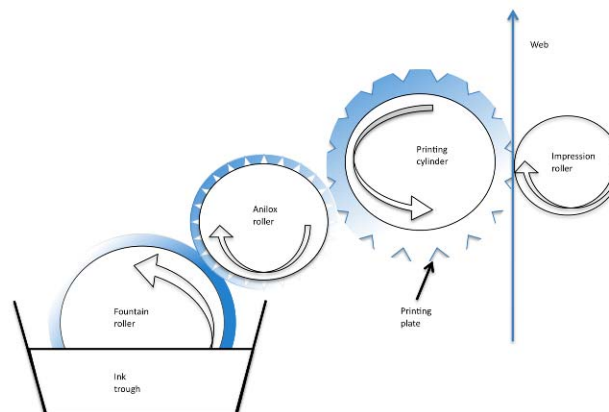
### 4.1 Coating Trials

Coating trials were carried out using 400 micron APET since this is a typical clear material routinely used to thermoform food trays. The ink chosen was ELAN™ formulated by Sun Chemical. This ink is water based – containing organic pigment in acrylic resin medium. Leading Edge Labels applied the ink in three different thicknesses.

The three samples had different amounts of ink and depth of colour. The double pass material having the heaviest coat weight followed by the single pass material and finally the 70% screen material was the lightest.

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**Figure 4:** Flexographic Printing Process



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**Figure 5:** APET sheet during printing



## 4.2 Thermoforming trials

The printed material was taken to TMB Patterns in Bridgwater. There the Sainsbury's 250g mushroom punnet tool was used to make impressions from each reel on an off-line single cavity thermoforming machine. This punnet measures L 177 x W 137 x D 60 mm.

**Figure 6:** Sheet Material being thermoformed



All the samples were easily thermoformed without giving any notable concerns. It is relevant to point out that the tooling used in this trial is usually used for PP so had a textured surface. This trial was with APET so the samples made had a texture, which gave a dull but satisfactory appearance to the finished tray. Further development work could be carried out to develop a gloss finish if required. It should be noted that none of the retailers who commented on the trays noted any concerns over surface quality.

**Figure 7:** Finished samples showing from left to right the different levels of ink coverage from double coat to single coat in the middle and 70% coating on the right.



## 4.3 NIR Identification and Sorting of Ink Coated PET Trays

NIR sorting trials were performed using a standard database for polymers used in packaging applications. All readings were performed using NIR and Visible (VIS) reflecting spectroscopy. The NIR and VIS Spectrum 'curves' are formed as averages based upon several readings. Normally, recognition rate of over 70% in NIR or VIS spectrum can be achieved from the polymer and colour database.

### 4.3.1 NIR Trial Results

NIR identification of the ink-coated trays demonstrated that the underlying polymer type could be identified. Samples coloured with a single pass ink (one layer) gave a strong signal and resulted in 100% PET polymer recognition.

## 4.4 Washing Trials

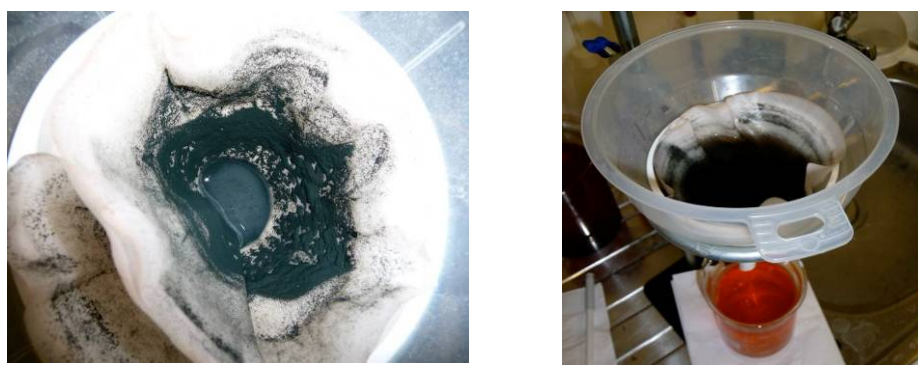
To assess ink-key and removability in a hot caustic wash process the following protocol was used:

The Association of Postconsumer Plastic Recyclers PET Bleeding Label Test is a test protocol designed to provide generic wash conditions for the evaluation of 'bleeding labels'. A 'bleeding label' is one with water dispersible or soluble inks that result in discoloured wash water. Using the principles of this methodology the following protocol was completed.

- The sample trays were cut roughly into 1cm<sup>2</sup> flakes.
- Water, caustic soda (40% NaOH) and detergent were heated on a hotplate with magnetic stirrer.
- Once the temperature reached 85°C the flake was added.
- After 15 minutes the material was filtered and the flake was collected for further assessment.
- The remaining liqueur was filtered and the residue dried and weighed.

### 4.4.1 Washing Trial Results

**Figure 8:** Wash liqueur being filtered (note the colour of the filtered solution)



**Figure 9:** Washed flake showing residual ink



The high temperature of the wash caused the flakes to curl due to reversion of the thermoformed shape and where the ink was trapped inside these curls full ink removal was not possible. The ink was soft and weakly held to the surface but was not separated from the flake. Where the flakes were flat, the ink was either completely or substantially removed. The textured pattern on the surface of the mould seemed to influence the stronger adhesion to the surface based on the residues seen on some flakes.

The 'scotch tape test' (ASTM-D3359 Test method for evaluating the adhesion of a coating to a substrate) results showed that there was very good ink 'key' or adhesion of the coating to the substrate. This indicates that there would be less risk of scuffing during normal handling routes to market, than an ink with a lower ink key and reduced degree of cross linking. Striking the balance between ink key and removing the colour in the recycling process is critical and further work would need to explore the variables affecting ink key and would also involve transit testing of filled containers to ensure that the ink did not become scuffed.

#### 4.4.2 Washing Trial Discussion and Conclusions

The washing trials of thermoformed PET trays that had been size reduced to simulate the recycling process showed the following:

1. The removal of the ink was possible on flat sheet samples prior to thermoforming. When conditions were optimised by the use of high temperatures ( $>75^{\circ}\text{C}$ ), 100% of the ink was removed.
2. The curling of the flake due to the reversion of thermoformed trays resulted in incomplete ink removal. The use of lower temperatures such as  $45^{\circ}\text{C}$  did prevent the flake from curling but resulted in lower ink removal efficiency.
3. The separation of the ink as a floating particle means that the standard washing conditions for PET provide a mechanism for separating and collecting the ink during the recirculation of the wash water. The wash water is normally screened and filtered prior to centrifuging the liquid to remove any solids. In this way the ink can be collected at the normal exit point for fibres, labels and other small contaminants. The inks (based on acrylic resins) could be harmlessly disposed of to landfill with the other labels and fibres after water removal.
4. The separation of the coloured filtrate from this specific pigment combination suggests that some of the dye used to prepare the pigment system has been converted from an insoluble to a soluble form. One way of treating this issue is to acidify the solution to re-precipitate the dye into a solid form. The advice from Sun Chemicals was that the problem can be treated in this way subject to confirmation in practice or different pigments could be used with greater resistance to alkaline solutions.
5. Further work should include an assessment of the effect of higher shear found in commercial wash plants on the ink removal. This work should also include development of the bonding forces between the ink and the substrate which can be altered by changing the degree of cross-linking and the surface finish of the coating.

#### 4.5 Food Packaging Compliance

The legislation that applies in the case of food safe packaging is the European Commission's Framework Regulation 1935/2004, which states that food contact materials shall be safe and that they shall not transfer their components into the food in quantities that could endanger human health, change the composition of the food in an unacceptable way or deteriorate the taste and odour of foodstuffs.

The ink used in these trials is not designed for intentional and prolonged direct contact with food. They are designed for use on the non-food contact surface – external to the package only and where the substrate acts as a functional barrier. As with all new food contact packaging overall migration testing would need to be completed before the packaging could be used.

##### 4.5.1 Food Grade Status of removable ink treated PET after recycling

An evaluation of the influence of the removable ink coating on the subsequent performance of the coated substrate was conducted by simulating the conditions encountered by PET flakes in a recycling process. The URRC hybrid UnPET<sup>®</sup> Process was used in this case. This process uses caustic soda to chemically etch PET flake and is recognised worldwide as a fully approved food grade recycling process. The flakes were then tested by GC-MS for any residues that could be attributed to the ink coating. The food-grade performance of the treated sample was then compared against the performance of a randomly selected batch of rPET that meets food grade standards after processing within the recycling plant.

The GC-MS traces for the ink coated PET after washing and standard food grade rPET are provided in appendix 1 and show the presence of any volatile substances. Samples of the ink-coated flake prior to washing were not analysed by GC-MS because untreated material would not be considered acceptable for food contact applications.

The two scales on the GC-MS traces are substantially different, so have been overlaid on the same scale (appendix 1) and show the relative presence of volatile substances. They show that there is no difference in the volatile behaviour of the two materials in this test. This suggests that both samples would comply with food grade regulations subject to testing.

**Note: All packaging should be tested for migration in the intended end use and with the specific packed products or approved simulants.**

#### 4.6 Retailer Feedback

Samples of the initial prototypes – made as dark brown produce trays, modelled on those used for mushrooms in Sainsbury's – were dispatched to a number of retailers for their views.

**Figure 10:** Original product purchased from store



**Figure 11:** Filled and wrapped 'single pass' samples



Each retailer received single and double-coated versions of the trays, along with imagery of the tray packed with mushrooms and asked to provide feedback on the aesthetic of the trays and to express any concerns or constraints they felt necessary for consideration.

#### 4.6.1 *Retailer's Comments*

- The difference between the single and double pass is minimal when filled. It was felt by most that colour level would be acceptable on the single pass.
- Retailers felt that it was good that the ink is applied to the external of the tray as then there is no food contact and things like sealing performance would not be affected. However they would insist that low migration inks be used.
- Retailers would like to see samples of the trays in other colours. The deep brown benefits from warm reds to provide a level of opacity, but keen to see colours such as pale blue and also reds to understand what the breakdown might be. It is recommended that ink suppliers and the retail supply chain experiment with other colours.
- A question arose over permanency of the inks during filling, transit and in-store handling. Samples that were received showed signs of scuffing on the corner areas, particularly on the double pass variant and this could become even more of an issue during de-nesting. It is recommended that ink suppliers and the retail supply chain continue work to optimise the coverage of removable ink and maximise scuff resistance.
- Retailers would like to see test data relating to the performance of the inks in freeze and chill conditions to understand compatibility between base material and ink in those conditions e.g. would one suffer from brittleness before the other? It is recommended that ink suppliers and the retail supply chain continue testing and if necessary development work, to ensure that the performance of the inks in freeze and chill conditions is acceptable.

## 5.0 Alternative Labelling Techniques

There is a growing trend in the food industry to use in-mould labelling to decorate pots and tubs. The concept is to coat the reverse side of the label with a heat seal layer and the fusing of the film label during the moulding operation causes the label to adhere to the container.

In-mould labels made from film offer better heat, moisture, and chemical resistance than those labels made from paper. There are also perceived recycling advantages with film labels. However, because the ink is trapped, recycling these containers can be difficult.

From sorting trials completed on commercially available Near Infrared sorting equipment earlier in this project, it was found that firstly if the label is made of a different substrate there can be difficulties correctly identifying the container by polymer using optical sorters and it may be lost from the recycling stream at this point. Secondly if the label substrate is the same as the container e.g. Polypropylene it will be correctly identified by polymer but will be sorted as a coloured item. This means that even if the container itself is made from natural or colourless material the use of the in-mould label will downgrade it to the coloured or 'jazz' stream. Even after shredding and washing, the label will still adhere to the flakes because they are permanently bonded together.

The use of removable labels can therefore divert material from the coloured or 'jazz' stream back to high value natural recycle.

An alternative means of adding colour to packaging is through the use of self-adhesive or pressure sensitive labels. Straight-sided containers are often labelled with full sized wrap around labels. Some of these containers are also coloured with masterbatch. Here the container is left natural and the label is used to carry the identity colour and the product information.

### 5.1 Shrink Sleeves

Marks & Spencer's Mini Bites were identified as an example of a large natural PP pot that is decorated using in-mould labelling. As an example of alternative labelling techniques that could be used to add the decoration without any loss of design quality, a shrink sleeve was created from original artwork and applied to the pot.

**Figure 12:** Shrink Sleeve on left hand image and current in-mould label on right hand image



This trial was to investigate the use of a shrink sleeve as an alternative to an in-mould label to yield a more easily recycled pack, while not detracting from the quality of the product presentation.

Shrink sleeves are fully removable and not attached to the container in any way. From the image above, other than a difference in the fonts used for the product name it is virtually impossible to tell the packs apart. This type of sleeve incorporating the tamper evident feature would be applied after filling. The packer here was

concerned that the heat from the shrink tunnels may be detrimental to the delicate chocolate products. It is possible with a little development to be able to apply the sleeve prior to filling and to retain the current tamper evident feature on the pot.

There were further concerns raised by the packer around the capital outlay required to install sleeving applicators and tunnels on five filling lines. It is recognised that this is a considerable outlay for a packaging supplier and it is estimated to cost in the region of £250,000 to do this.

## 5.2 Self-peeling wash-off labels

An alternative means of adding colour to packaging is through the use of self-adhesive or pressure sensitive labels. Straight-sided containers are often labelled with full sized wrap around labels. Some of these containers are also coloured with masterbatch. Trials were completed to evaluate the benefits of leaving the container natural and using the label to carry the identity colour and the product information.

One new development is the 'self-peeling' label by Avery Dennison which is based on the principle of differential expansion under thermal conditions. The labels fully adhere to the packaging item under ambient temperatures, however at higher temperatures  $>50^{\circ}\text{C}$  the expansion of one layer within a two layer film causes differential expansion, thus resulting in peeling of the film away from the packaging item under caustic conditions. The key advantage of this system is that the adhesive stays on the label and does not end up in the hot-wash tanks or on the rigid packaging item.

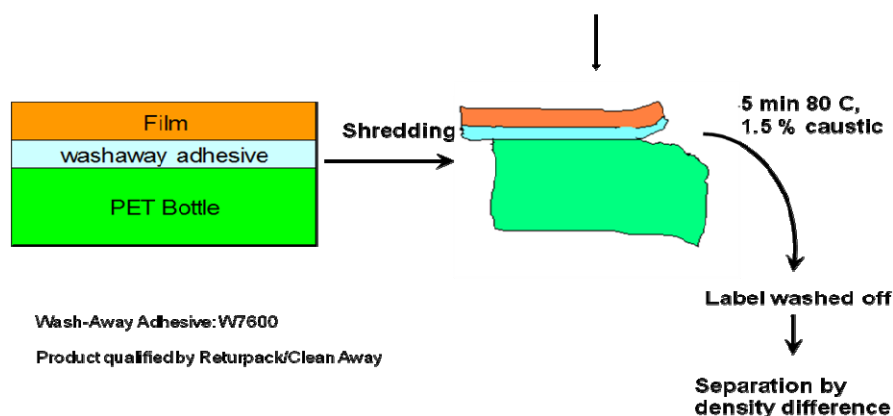
The label substrate is also matched to the bottle substrate so that they will always separate by sink-float separation. In this trial the pots to be labelled were HDPE and so the label was made from PET film.

The labels used in the trial were surface printed with the ink on top of the film. In this case there is a risk that inks may dissolve into the caustic liquid or flake off from the film. However using sub surface printing will prevent this from happening. It is also possible to embed the print between the film layers, by over-laminating the print with the second film layer. This avoids inks contamination of the caustic bath.

### 5.2.1 Recyclability of Packaging Items with Wash-off Labels

The labels can be removed whole if 'whole bottle wash' systems are available or can be removed after size reduction to flake. One key advantage is that the adhesive does not dissolve into the wash water and stays with the label substrate during the washing process.

**Figure 13:** Demonstration of label removable from PET bottle flakes (Source: Avery Dennison 2009)



**Figure 14:** Images of samples with self-adhesive labels



The image above is of typical products decorated with self-adhesive labels.

On the right are samples of a natural HDPE pot decorated with a self-adhesive – wash off label.



### 5.2.2 Washing Trials

The labels were applied to the natural HDPE pots by hand, allowed to 'wet out' for an hour and were then cut into flakes of approximately 1cm<sup>2</sup>.

**Figure 15:** Flake prior to washing



A caustic solution was prepared as per earlier trials and heated to 85°C. The flake was washed for 15 minutes then drained and rinsed in cold water.

The images below show the washed flake after 15 minutes and during draining where the discolouration of the wash liqueur can be seen. On this occasion the wash liqueur was not filtered or recovered for any further work as this trial was to assess the label removal during washing.

**Figure 16:** Washed flake after 15 minutes

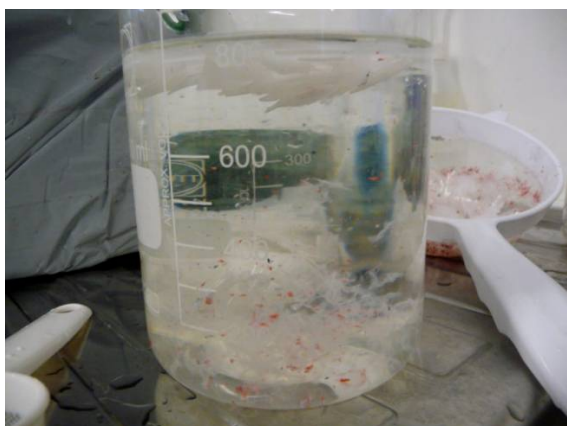


After the sample had been cooled and rinsed it was relatively straightforward to separate the HDPE flake from the label fragments using sink-float separation, as demonstrated in the images below.

The HDPE flake was clean and had no remnants of label or adhesive adhering to it and gave a very high quality recyclate that did not pick up colouration from the inks in the wash water.

The label fragments remained intact and the only concern was that they were tacky. However, it is unlikely in a real life recycling scenario that all the light material would be label stock of this type so in fact other light material and dust would be collected by the adhesive and carried out of the system in the air classifier.

**Figure 17:** HDPE flake (float fraction) the label flake (sink fraction)



**Figure 18:** Clean HDPE flake after washing



**Figure 19:** Label fragments after sink-float separation



### *5.2.3 Conclusion of Wash off Label Trial*

In conclusion the wash off label worked very well and gave an excellent quality of HDPE flake. This 'self peeling label' technology has not yet been adopted within the plastics packaging industry as it is novel and has only recently been commercialised. These labels can be applied by standard self adhesive label applicators.

It can be concluded that this type of label would improve the recyclability of containers that are currently labelled with self-adhesive labels and these new label materials would greatly improve the quality of the final recycle. As mixed plastic recycling begins to incorporate other packaging items it could be used as a means of adding colour and decoration as well as making the overall pack more recyclable.

## 6.0 Economic Viability Assessment

An evaluation was completed to compare the economic impacts of alternative technologies for removable colour with their existing packaging samples.

### 6.1 Cost Model Scenarios

**Table 1:** Overview of the scenarios modelled

Example	Pack Type	Current Technology	Alternative Solution	Scenario
Mushroom Punnet	Thermoformed PP	Pigmented sheet, sealing film and label		A
			Clear APET sheet, direct print removable ink	B
Laundry Powder Pot	Extrusion blow moulded HDPE	Pigmented material, large self adhesive paper label		C
			Clear material, stretch sleeve	D
			Clear material, self-peeling label	E
Cookie Pot	Injection moulded PP	Clear material, in-mould label		F
			Clear material, shrink sleeve	G

#### Scenario A – Mushroom Punnet: Current Technology

The current technology is based on PP with 2% masterbatch added during the sheet extrusion process to provide a brown colour.

#### Scenario B – Mushroom Punnet: Clear Sheet with Direct Removable Ink Print

In the alternative technology solution, unpigmented clear APET sheet was extruded. The sheet was then printed with removable ink to provide the brown colour.

#### Scenario C – Laundry Powder Pot: Current Technology

The current technology is based on HDPE with 1.5% coloured masterbatch added during the extrusion blow moulding process. A large self-adhesive paper label is then applied, covering most of the surface.

#### Scenario D – Laundry Powder Pot: Clear Material with Stretch Sleeve

In this alternative solution, the colour masterbatch was not used and clear HDPE pots were blow moulded. A stretch sleeve then replaced the current label. The stretch sleeve would provide the solid colour as well as label information.

#### Scenario E – Laundry Pot: Clear Material with Self-Peeling Label

The colour masterbatch was not used and clear HDPE was used as in Scenario D. A self-peeling label replaces the current label.

#### Scenario F – Cookie Pot: Current Technology

The current technology is based on natural PP injection moulded pots. A large in-mould label is automatically placed in the tool prior to injection of the PP and becomes bonded to it as the pot is cooled.

#### Scenario G – Cookie Pot: Clear Material with Shrink Sleeve

The Cookie pot was injection moulded using natural PP but without the in-mould label. A shrink sleeve was applied after filling, with reverse printing providing the body colour as well as the label graphics. The pack would then be conveyed through an oven to shrink the label into place.

## 6.2 Packaging Cost Data

**Table 2:** Table of indicative material costs for each scenario

Scenario	Packaging Type	Components	Cost per 1000 units	
		£ per 1000	Current	Proposed
<b>A Mushroom punnet</b>	Masterbatch pigmented sheet Based on a masterbatch price of £5.60/Kg and 2% addition rate and PP price of £1120 / tonne:	1.50 (m/b) + 14.50 (PP punnet)	= £16.00	-
<b>B Mushroom punnet</b>	Removable ink coated sheet (PET) Based on a coat weight of 2.5gsm at £0.03 / m <sup>2</sup> And PET price of £932 / tonne:  Equivalent cost for PP punnets:	0.85 (ink) + 12.25 (PET punnet)  0.85 (ink) + 14.78 (PP punnet)	-	= £13.10  or (£15.63 PP)
<b>C Laundry powder pot</b>	Masterbatch pigmented pot & wrap around label. Based on a masterbatch price of £11.72 / Kg. at 1.5% addition rate and HDPE price of £988 / tonne:	4.83 (m/b) + 26.76 (HDPE pot) + 11.00 (label)	= £42.59	-
<b>D Laundry powder pot</b>	Clear pot with stretch sleeve:	27.22 (HDPE pot) + 15.50 (sleeve)	-	= £42.72
<b>E Laundry powder pot</b>	Clear pot with self-peeling wash off label:	27.22 (HDPE pot) + 29.50 (label)	-	= £56.72
<b>F Cookie pot</b>	Clear pot with in-mould label based on PP price of £1120 / tonne:	33.13 (PP pot) + 30.50 (IML)	= £63.63	-
<b>G Cookie pot</b>	Clear pot with shrink-sleeve:	33.13 (PP pot) + 43.00 (sleeve)	-	= £76.13

The table above shows the indicative material costs of the alternative solutions. It does not include application costs or processing and contribution to overheads costs except for scenario B where this price includes the cost of the ink and the application / printing costs. Application costs for labels and sleeves are not included here because they vary widely based on the type of applicator, the line speed and the range of sizes that would be required to be included and whether this would be carried out in-house or by a third party. The costs shown are indicative of generic pack types and have been obtained from thermoformers and label and sleeve printer / converters.

## 6.3 Recyclate Cost Data

Production of a clear / natural recyclate will earn re-processors an extra £300 per tonne as shown in the table below. The overall benefit to the reprocessor depends on the recycling rate and volumes of material handled as well as the value of PRNs and disposal costs.

**Table 3:** Approximate value of reprocessed plastic materials

Recyclate Value	Jazz / Coloured	Clear/Natural
rPET	£500/te	£800/te
rHDPE	£500/te	£800/te
rPP	£500/te	£800/te

Landfill costs, based on the current median are calculated to be a total of £88.00/te including gate fees and transport. The average value of PRN/PERNs over the past three years is £17/te of reprocessed material.

## 6.4 Results

### Mushroom Punnet Results

The alternative technology solution scenario B (direct print) is lower cost compared to the current technology scenario A (coloured masterbatch) based on the use of non-heavy, metal pigments and total colouration of the whole sheet. In addition if the printed area is restricted to the zone of the sheet that will be thermoformed, then the amount of ink used could be reduced, by up to one third. It should be noted that lower cost pigments are available, although these are not always used for food contact materials.

The actual situation will be dependent on the pigments being replaced and the direct print cost, which would need to be verified on a case-by-case basis. However the removable ink process seems to be commercially competitive.

In this example costs have been obtained from a manufacturer of coloured thermoformed trays where they extrude their own sheet material and incorporate masterbatch as required. To convert this process to a direct print process would involve investing in printing presses. As an alternative and faster route to market this example shows the cost of having colourless sheet extruded and coated off-site at a specialist printer. It omits transport costs because that would be negotiated locally.

Scenario B also has a positive economic impact over Scenario A to the reprocessor. This is because the material could be recovered into the clear stream, which has a higher value than the coloured “jazz” stream reached by material in Scenario A.

### Laundry Powder Pot Results

The alternative technology scenario D (stretch sleeve) is of the same order of magnitude compared to the current scenario C (masterbatch and self-adhesive label). This is due to the elimination of the coloured masterbatch, which in this example is a high-end bespoke pigment. The replacement of less expensive pigments may not provide the same costs savings and justification for a switch to stretch sleeves.

The economics for Scenario E (self peeling wash off label) show that this label is approximately twice the cost of the other systems. This is due to the novel nature of the self-peeling labels and the level of sophistication needed in their manufacture over a standard single ply reverse printed PE stretch sleeve.

The cost of application in this example has been excluded because there is no change in capital equipment needed to convert from the current self-adhesive label to the self-peeling label. A switch to stretch sleeving would however require replacement of applicators. This is likely to be done when existing equipment is due to be replaced as part of a capital investment programme as the cost of stretch sleeving applicators is comparable to the cost of self adhesive label applicators.

Scenarios D and E both have a positive economic impact over Scenario C through reprocessing. This is because the material could be recovered into the clear plastic stream, which has a higher value than the coloured plastic stream reached by material in Scenario C.

### Cookie Pot Results

Scenario G (shrink sleeve) is more costly than the standard Scenario F (in-mould label) and would require additional equipment and costs to apply the sleeve in-line, making this less attractive to adopt. By reference to the costs for stretch sleeves (Scenario D), it is possible that some containers that have parallel sides or low taper could use stretch sleeves.

Scenario G also has a positive economic impact over Scenario D through reprocessing. This is because the material could be recovered into the clear plastic stream, which has a higher value than the coloured plastic stream reached by material in Scenario F.

## 6.5 Conclusions

Direct printing technology could be competitively used to replace coloured masterbatch for mass colouring of thermoformed packs. The mushroom punnet example assumed no change to the self-adhesive label applied or the overwrap film.

The application of stretch sleeves to packaging is relatively low in cost compared to the other technologies examined and requires low capital and processing costs making it an attractive option to investigate where the shape of the package allows.

Shrink sleeves and self-peeling wash-off labels produce their principle benefit to the sustainability of the package at the stage of the recovery of the material.

Implementation of removable colour technologies will, at least in some cases, realise economic benefits but may also require the re-configuration of the recyclers' process to maximise recovery. For example, direct printing with removable inks requires a colour-sorting step after the wash process for recovery of the clear material.

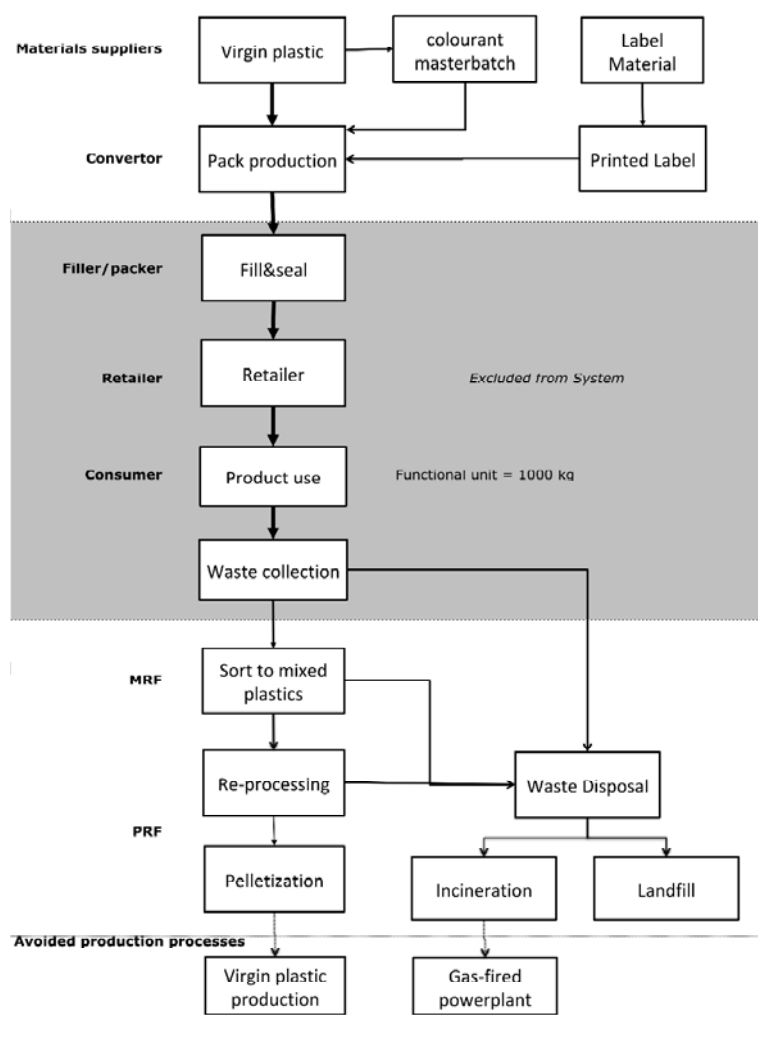
Even though some of the colouration technologies discussed above are not cost competitive with the standard methods of colouration by pigmentation, the switching of technologies may not have a significant impact on the final cost of the package. Also other drivers such as a policy implemented by retailers to improve the recyclability of packaging may allow these technologies to be adopted and the improved economics to be realised at the recycling operations.

## 7.0 Environmental Assessment

An evaluation of the environmental viability of the removable colour packaging solutions compared the environmental impact of manufacture and recycling of packaging formats against the standard coloured packs that they could replace. All other elements of the supply chain such as product filling of the packaging, wholesaling, retailing, purchasing, consumption and disposal to waste collection facilities were assumed to remain unchanged.

### 7.1 System Boundaries

Figure 20 General Diagram of Systems Boundary of environmental assessment of removable colour systems <sup>2</sup>



Included in the system boundary are the end-of-life treatments of recycling, with municipal incineration and disposal to landfill of the residue. It has been assumed that removable colour systems will not change recycling rates per se. The functional unit for the assessment was per 1 tonne of coloured plastic packaging sent for recycling.

The method of system expansion was used to calculate the avoided impact of production of virgin polymer due to substitution by recycled polymer. Residues sent for incineration also result in avoided impact due to the decreased demand for energy production by gas-fired power plants.

<sup>2</sup> For clarity, provision of electrical power, fuels, etc. are omitted from the diagram, but are included in the assessment

## 7.2 Environmental Assessment

**Table 4:** GWP100 (kg CO<sub>2</sub>-equiv/tonne) impacts within the packaging lifecycle of Scenario A - G

	Polymer production	Package manufacture	Disposal / Incineration	Recycling activities	Avoided energy	Avoided polymer	Total
Scenario A	1983	563	86	790	-46	-1696	1679
Scenario B	2009	629	86	790	-46	-1696	1771
Scenario C	1826	1322	164	790	-58	-1668	2376
Scenario D	1897	1146	87	790	-46	-1668	2206
Scenario E	1853	1317	164	790	-58	-1668	2398
Scenario F	1935	1415	86	790	-46	-1696	2484
Scenario G	1880	1535	86	790	-46	-1696	2548

By comparing Scenario A (pigmented mushroom punnet) and Scenario B (mushroom Punnet with removable ink), it was seen that the removable colour system has a slightly higher environmental impact in the production phase, primarily due to the fact that direct printing requires sequential sheet extrusion and thermoforming, while Scenario A allows for the more efficient in-line sheet extrusion. Data for the environmental impact of manufacture of the removable ink in Scenario B was not available therefore the assessment assumed that the ink manufacture and pigment manufacture have the same impacts. As the colourants are a very small proportion of the total mass of the packaging, this assumption is not expected to be significant.

The variation in environmental impacts resulting from the trials show that global warming potential was 5.5% higher and water use 1.6% higher for Scenario B than the reference Scenario A. As with all trials, the results may not be representative of commercial scale operations.

Results were compared between Scenario C (coloured HDPE with label), and Scenario D (stretch sleeve over unpigmented HDPE). The use of a stretch sleeve as a removable colour system appears to improve the environmental performance of the package slightly, with a 7% reduction in GWP100 and energy demand, a 2.4% reduction in abiotic depletion potential (ADP), but a 10% increase in water consumption.

Wash-off labels in this analysis are modelled similarly to normal pressure-sensitive adhesive labels. There are not any significant changes in the production impacts expected. Environmental impacts from the models are similar between Scenario C (coloured HDPE with a label) and Scenario E (unpigmented material, with a self peeling label).

In Scenario G (unpigmented material, with a shrink sleeve), the use of a shrink sleeve is modelled against the use of in-mould labelling in an injection moulded PP pot (Scenario F). The results show a slight worsening in GWP performance for the shrink sleeve over conventional in-mould labels. The values for ADP and energy use are slightly improved in Scenario G, but there is a large increase (10%) in calculated water consumption.

## 7.3 Conclusions

Changing from pigmented PP to clear PP direct printed with ink has a slightly detrimental environmental impact. This should be treated with caution, as no environmental impact data was available for the removable inks for direct printing, or of the brown pigments for plastics colouration. However the slightly increased impact due to the direct printing process and going from in-line to sequential extrusion and thermoforming was largely balanced by the savings due to no longer requiring the extrusion compounding of masterbatch, giving an increase in environmental impact in the model going from Scenario A (colour masterbatch) to Scenario B (direct printing).

In summary, direct printing could substitute coloured masterbatch use without significantly increasing the environmental impact of the packaging system.

Changing from pigmented HDPE to clear HDPE through the use of a removable stretch sleeve was shown to result in a slight improvement in all environmental indicators except water use.

Wash-off labels show insignificant change in environmental performance, which is to be expected, as there is minimal difference between a wash-off label and a normal full-body label.

Changing from in-mould labelled PP pots to clear PP pots with a shrink sleeve was shown to have a net improvement against abiotic depletion and energy demand indicators, but an increase in environmental impact on GWP and water use. Again, the modelled differences were small, and may not be statistically significant.

It should be noted that it has been assumed that removable colour systems will not change recycling rates or yields of material recovered per se. The environmental benefit of these removable colour systems may also depend on whether they affect either the amount of recycling (due to economic benefit), or the quality of the recyclate, such that the substitution ratio of recycled material to virgin plastic is improved.

## 8.0 Project Conclusions

**Colour has always played a primary role in branding and packaging. It is used to convey messages or trigger associations that encourage the consumer to buy. It is also used to convey information about who a product is aimed at or how it is made.**

**Alternative systems and novel coatings for plastic packaging that could be used or that are currently being used to apply decoration have been reviewed in depth, in order to identify a range of solutions that could be developed as alternatives to the strong master batches currently used to create coloured plastics.**

**The objective of these changes will be to maintain the shelf appeal and product differentiation but also allow these packs to be recycled into colourless materials. This would result in higher market value for the recycled material and access to a wider range of end markets.**

Of the coating systems researched some like the SIPA Smartcoat™ were only available for PET bottles. Irregularly shaped packages are not suitable for a dip and spin coating technology, and it may not be possible to produce opaque colours with the coatings. While others like the PPG Bairocade coating would appear suitable for providing removable colour coatings to a range of plastic packaging items, so long as translucent colour coatings are acceptable. Application by electrostatic spray may increase the variety of shapes that could be effectively coated beyond the cylindrical bottles and jars coat-able by the SIPA Smartcoat™ system although the oven curing process may be a barrier to adoption for some packs.

All packaging requires labelling to carry important information about the product. It is possible that externally applied labels could also be used to carry any colour coding that is currently applied to the pack by the use of masterbatch.

The self-adhesive labelling system investigated was the Avery Dennison wash-off label technology. It is available although it has not yet been adopted within the packaging industry as it is novel and has only recently been commercialised. The labels can be applied to a variety of polymers commonly used for packaging. Trials proved that after size reduction the label washes off the flake substrate (HDPE) leaving the flakes without any traces of adhesive or ink residue. The label particles also easily separated in water from the HDPE flake through having different densities. In the laboratory trials carried out during this project the HDPE flake floated while the label fragments sank to the bottom. Actual recycling performance in industrial plastics reclamation and reprocessing plant would need to be evaluated to ensure that label removal away from the recovered flake is effective.

The findings of the NIR trials suggest that printed packaging is readily identifiable and the colour sort decision depends upon the level of most common colour. However sorting of packaging with self-adhesive labels is less straightforward. It was found that the opaqueness and thickness of labels played a significant role in the sensors ability to identify the polymer type of the pack. Labels with clear areas allowed for easy identification, and heavily printed thicker gauge labels resulted in difficulties with identification. There is therefore an opportunity for retailers and brand owners to work with label manufacturers to optimise label thickness to allow for the identification of the main packs. Overall, the majority of packs can be readily identified; however the decoration method plays a significant role in determining the effectiveness of the detection and sorting.

The use of ink as a means of applying removable colour to thermoformed packaging was investigated in depth and proved to be a viable alternative to masterbatch. The sheet material was printed with differing levels of ink and all demonstrated good ink key and resistance to scuffing. During thermoforming the ink did not scuff or split and the resultant trays had good visual attributes. By applying the ink to the outside of the packaging it reduced the food safety risks and ink approved for indirect contact with food was used.

Ink removal trials were carried out under varying conditions but did not produce completely clean flakes. However, a significant amount of the ink was removed and with some further development work it should be possible to develop a system that gives good scuff resistance and is fully removable in conventional washing processes. One of the problems relating to this is the fact that after thermoforming the material is very thin and the wall sections are stretched. During hot washing the heat causes the flaked material to shrink and as it does it curls, trapping ink on the inside surface. This means that there is very little turbulence within these tubes and so the wash processes which utilise temperature, caustic and turbulence are less able to remove the ink. All of the flakes that were flat after washing had the ink completely removed. Further trials in a commercial wash plant with higher shear would determine whether further development work on the ink-key is necessary.

The washed PET flake samples were also treated to a laboratory scale URRC process<sup>3</sup> used to render recyclate safe for use as food contact material. The resultant flake was then evaluated by gas chromatography (GC headspace) and compared to a batch of standard recycled PET. The results indicate that there is no difference in the volatile behaviour of the two materials. This would indicate that both samples would comply with the food grade regulations. As with all new food contact packaging overall migration testing would need to be completed before the packaging could be used.

Finally samples of the trays together with photographs of filled mock-up samples were sent to seven major UK retailers. The Packaging Managers were asked to comment and provide feedback on the appearance of the trays and to express any concerns or constraints they felt necessary for consideration for further development. Six of the seven responded and gave very positive feedback and made valid comments.

This part of the project had been conducted with PET since it required no significant pre-treatment prior to printing. The use of other plastics such as PP, HDPE, PVC and PS would also need to be validated to understand the validity of this approach. In general these polymers would be expected to release the inks more readily than PET.

The packaging items that could be made with this system of colouration should be constrained at the moment to containers with a shallow draw as this would be less demanding for this system to work successfully at this stage of development.

Overall the project found that there are viable technologies to enable colour to be removed from rigid plastic packaging during the recycling process that will have relatively little impact on the environment. If these technologies are to be promoted to the packaging supply chain then the mixed plastics recycling stream would ultimately have a higher value and the recovery of mixed plastics would be more attractive to recycling businesses. It has been assumed that the recycling rate, recovery yields and rate of virgin plastic substitution would be the same. If the recycling/recovery rate improved, the improved environmental impact of a higher rate of mixed plastics recycling would very quickly outweigh any of the slightly negative impacts associated with the adoption of some of the technologies.

The status of the various technologies can be summarised as:

1. Removable ink is a process that showed promise as a means of adding colour but needs further development to make it commercially viable. It is recommended that ink suppliers and the retail supply chain (including retailers and packaging converters/manufacturers) continue with testing and development work. Areas to test and develop further include; a wider range of colours, optimisation of depth of colour, scuff/scratch resistance, performance in freeze/chill conditions, and migration testing.
2. Use of shrink-sleeves as an alternative to in-mould labels gives immediate benefits for recycling but adds capital cost for the application equipment.
3. Use of stretch-sleeves or self-peeling labels as an alternative to masterbatch for certain types of container gives immediate recycling benefits and for sleeves financial benefits.

There are minor technical issues associated with the full roll out of the removable ink technology that can be resolved by further detailed research and there are financial considerations limiting but not preventing the adoption of the label and sleeve technologies. The adoption of these technologies to a wider range of packaging could be encouraged with flagship products and campaigns by industry or packaging organisations, brand owners, retailers and packaging businesses promoting these recycling friendly forms of colouration and decoration.

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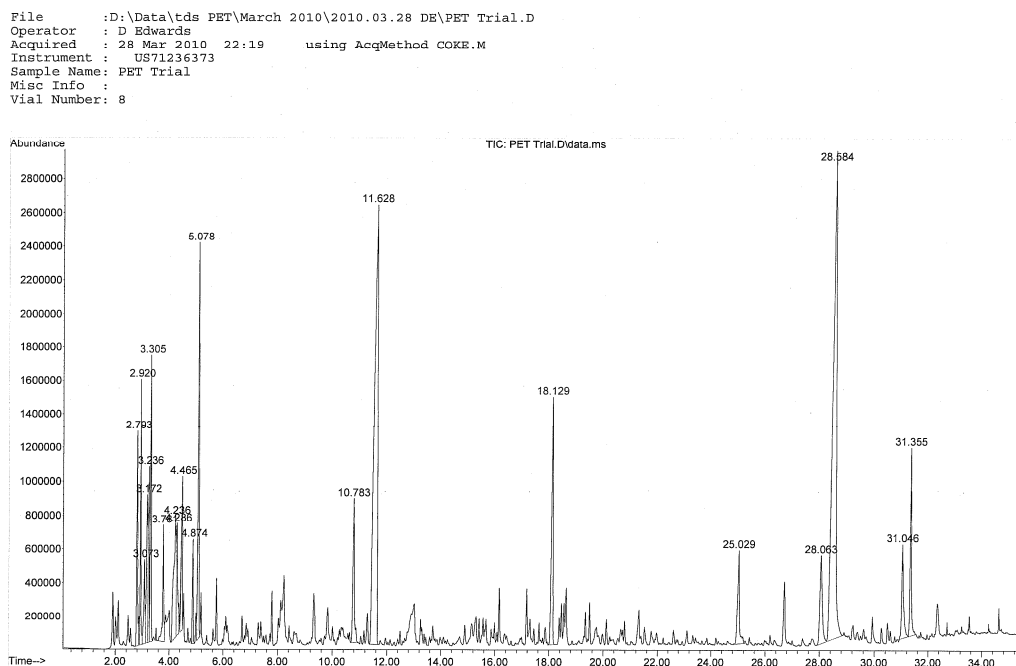
<sup>3</sup> URRC hybrid UnPET® Process that used caustic soda to chemically etch PET flake and is recognised worldwide as a fully approved food grade recycling process

**Table 5:** Summary of the characteristics and benefits of the systems investigated

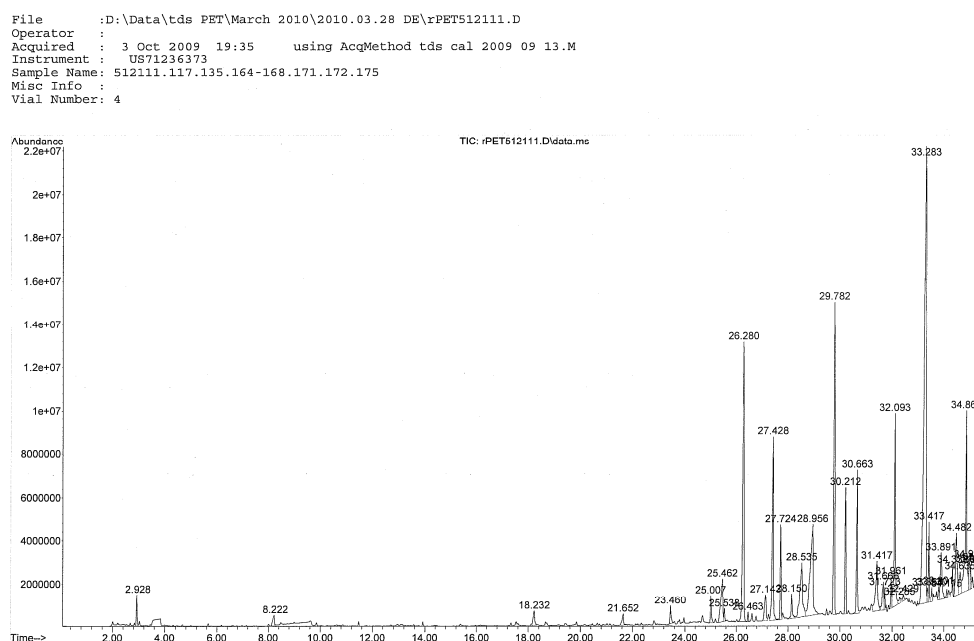
	<b>Ink as a coating</b>	<b>Shrink-sleeves</b>	<b>Self-peeling labels</b>
Packaging types covered	This would cover all shallow draw thermoformed coloured trays and punnets. Generic mushroom punnet annual volume estimated 300 million.	This would replace all large food grade natural polypropylene pots that are currently decorated with In Mould Labels (IML's) and therefore cannot be recycled back to food-grade.	This would cover all packaging where the primary pack is to be recycled e.g. bottles and pots and tubs currently decorated with self adhesive or wet-glue labels that don't wash off. Laundry powder pot annual volume estimated 30 million.
Overall System Benefits	Will allow coloured packaging to revert to colourless during recycling.	Will allow recovery of large natural food grade containers that are lost due to the colour in IML's.	In conjunction with natural polymer containers, will allow recovery of un-pigmented polymer. Effective removal of label from flake may improve yields where recycling processes remove flakes still attached to label fragments.
Cost Benefits	Initial capital outlay offset by ongoing reduction in unit costs.	Initial capital outlay and more expensive labels but by moving packs from a jazz low grade recycling stream to natural grade or even food grade material streams. This helps reprocessors.	More expensive but with widespread adoption production costs may come down. Cost benefit to reprocessors due to higher yields.
Soft Benefits	No masterbatch. Registered print allows skeletal waste to be re-used in any same polymer product. Potential to add more detailed decoration other than just one solid colour.	Total pack recovery for recycling. Sleeve film will be recovered via air classifiers so most likely to be energy recovered and primary pot / tub will be recovered as high-grade recycle.	Potential increase in yields through recycling processes. Currently flake sorters remove a % of natural flake with every coloured flake (label fragments cause flake to be identified as coloured) by removing the label not only is that flake recovered but those other flakes that would have been rejected at the same time are also recovered.
Process Changes Required	Installation of printing line between extruder and thermoformer. Recycling systems will need to include colour sorting after washing to recover natural and colourless flake.	Sleeve applicators and shrink tunnels would need to be installed. This could be carried out by the pot manufacturer, which would mean there would be no change for the packer/filler. Or could be applied at point of fill, so stock holding items could be greatly reduced.	No changes required – straight technology transfer if already using self-adhesive labels.
Further Development Considerations	As per current requirements, the food safety status of ink coated materials must be verified by appropriate migration testing. Robustness of the ink through normal distribution cycles and full removal of the ink in commercial wash plants with high shear would need to be tested.	Sleeve material choice needs consideration. PVC is a low cost material but would not be welcomed by re-processors.	Label substrate matched to pack type to ensure density separation. Commercial scale recycling trials needed to test label fragment removal in air separators as well as sink-float separation.

# Appendix 1 GC-MS Traces

**Figure 21:** GC-MS trace showing the peaks representing the analytes present in the ink-coated PET test material after washing trials to remove ink (see section 4). The mass spectrometer has identified the analytes represented by the peaks.

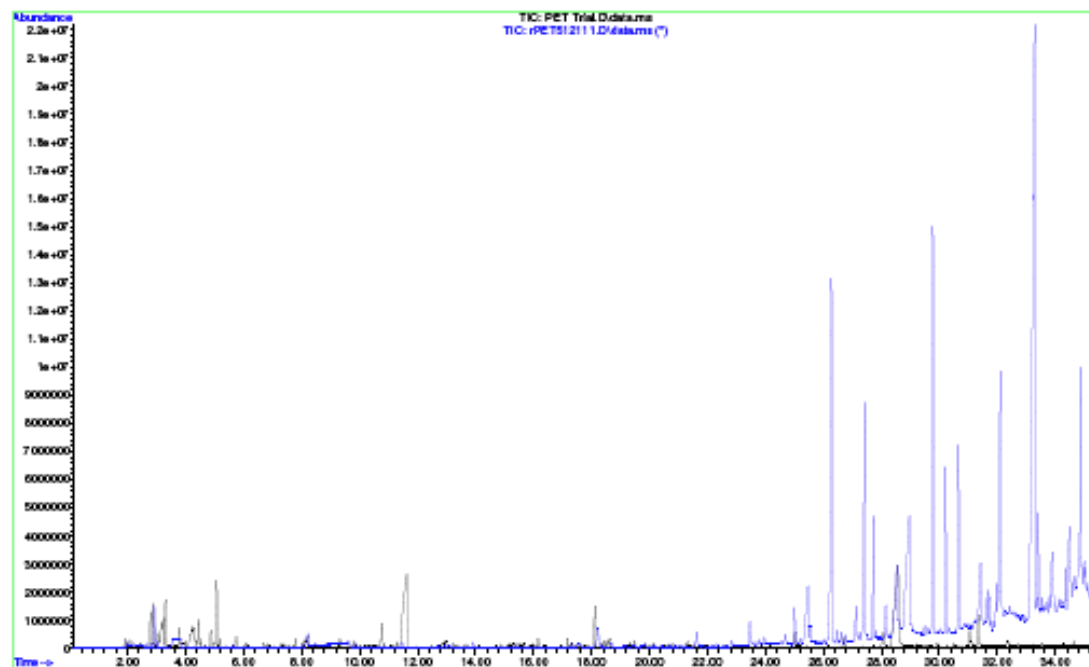


**Figure 22:** GC-MS trace showing the peaks representing the analytes present in typical food grade rPET (colourless). The mass spectrometer has identified the analytes represented by the peaks.



**Figure 23:** Overlay of figures 25 and 26. The traces in figure 25 and 26 are to different scales; here they are overlaid on the same scale to allow a comparison and to identify any atypical peaks.

```
File       : D:\Data\tda PET\March 2010\2010.03.28 DE\PET Trial.D
Operator   : D Edwards
Acquired   : 28 Mar 2010  22:19   using AcqMethod COKE.M
Instrument  : US71236373
Sample Name: PET Trial
Misc Info  :
Vial Number: 8
```



# Appendix 2 Retailer Feedback

## (Comments on a visual review of the ink coated mushroom trays)

### Retailer 1

- The difference between the single and double pass is minimal and when filled, it was felt that colour level would be acceptable on the single pass) and if made a more cost effective output then they would be keen to see how this variant could be made acceptable;
- Good that the ink is applied to the external of the tray as then there is no food contact and things like sealing performance would not be affected; however, would insist that low migration inks be used;
- Would like to see samples of the trays in other colours ... The deep brown benefits from warm reds to provide a level of opacity, but keen to see colours such as pale blue and also reds to understand what the breakdown might be; and
- A question over permanency of the inks during filling, transit and in-store handling ... samples that were received showed signs of scuffing on the corner areas – particularly on the double pass variant – and this could become even more of an issue during de-nesting.

### Retailer 2

- Very pleased to see these first samples and they far exceeded expectations!
- Echoed the responses of Retailer 1 in terms of concerns over migration of UV inks and specification of low or no migration inks would be very important;
- Would like to see test data relating to the performance of the inks in freeze and chill conditions to understand compatibility between base material and ink in those conditions, e.g. would one suffer from brittleness before the other;
- Would also like to see data relating to moisture resistance;
- Would be useful to have both a benchmark coloured tray and clear tray for physical comparison in the next round of prototypes;
- Feels that the level of colour achieved on both the single and the double pass is acceptable and wouldn't want to get too focussed on achieving greater opacity, when filled, this proved not to be as big an issue ... again, particularly if it helped deliver a cost-effective solution.

### Retailer 3

- Overall, the look and finish of the trays were felt to be perfectly acceptable – with a slight preference for the double pass tray as it offered a more solid colour.
- Again, keen to see a wider application of colours to see how the trays look in both dark and light colours.
- The trays need to be able to de-nest easily and perform in a number of different environments that vary in humidity and sealing techniques, e.g. lidding films and shrink-wrap.

### Retailer 4

- Felt that the colour was not deep enough but this may be a perception issue and could be improved with black
- The fact that the ink is applied to the exterior of the tray will reduce migration issues, but testing data would need to be provided to demonstrate compliance.
- Initial thoughts were that they would be ideal for trays for assorted chocolates, as an easy win.

### Retailer 5

- Initial feedback is that the trays look good although the depth of colour could be higher
- Some concerns over the type of ink used and food safety with the risk of ink transferring from the outside of the tray to the interior of the next one during stacking
- Would like to see the full environmental benefit of using a wash off ink versus a standard coloured plastic tray that is recycled into lower grade mouldings
- Would be very happy to support further development on this prototype

### Retailer 6

- Initial feedback is that the trays are generally looking good
- The double-pass variant appears to offer a preferable level of opacity
- Would like to see greater exploration of colours and understand how the colour might vary (if at all) on different tray depths, as the material would stretch into the corners, etc.

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